Diurnal change of gas exchange of *Rhodiola sachalinensis* transplanted from different habitats in Changbai Mountain[1]

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Abstract *Rhodiola sachalinensis* growing in the different habitats, such as Xiaotianchi plot (altitude 1 800 m), Tree line plot (altitude 2 000 m) and Tianwenfeng plot (altitude 2 325 m) of Changbai Mountain (northern slop) were transplanted to Harbin Experimental Farm for determining its gas exchange. The study results indicated that the diurnal changes of gas exchange of *Rh. sachalinensis* transplanted from different habitats were still different though the morphological appearance of the newly sprouted above-ground part had become more similar. For net photosynthesis rate (Pn), stomatal conductance (Gs) and apparent quantum yield (AQY), the diurnal change curves of *Rh. sachalinensis* transplanted from the three plots were similar, but the data value were different. For the dark respiration rate (Rd), transpiration rate (Tr) and water use efficiency (WUE), diurnal change curves of the three plots were obviously different.

Key words: *Rhodiola sachalinensis*, Transplanting, Gas exchange, Diurnal change

Introduction

Rhodiola sachalinensis A. Bor is perennial herb that belongs to Crassulaceae. It mainly distributes in Japan, Korea, China and Russian. In China it mainly distributes at the altitude of 1 770-2 500 m in Changbai Mountain of Jilin Province and Zhangguangcai Mountain of Heilongjiang Province. It is typical alpine plant (Wu *et al.* 1987; Qin 1994; Lu *et al.* 1995) and also very important medicinal plant. From 1950s a lot of research work about *Rhodiola* plants had been done in Russian, Ukraine, Japan and China. But the research work about physiological ecology of *Rhodiola* plants is still little (Yan *et al.* 1999a).

At the northern slop of Changbai Mountain that locates at the southeast part of Jilin Province, the plants of *Rh. sachalinensis* show obvious morphological difference in different habitats, and the character of gas exchange (determined in the field) of *Rh. sachalinensis* is also very different in different habitats (Yan *et al.* 1999a). The plants of *Rh. Sachalinensis* of different habitats were transplanted to a place with same environment condition, the newly sprouted plants showed no obvious morphological difference and the state of growing was becoming more similar. But the difference of physiological metabolism still was remained after the transplantation (Yan *et al.* 1999b). In this article, the difference of diurnal change of gas exchange of *Rh. sachalinensis* transplanted from different habitats was analyzed.

Materials and methods

Materials and cultivation after transplanting

In the research work, we chose three plots with different elevations in the northern slope of Changbai Mountain, such as Xiaotianchi plot (altitude 1 800 m), Tree line plot (altitude 2 000 m) and Tianwenfeng plot (altitude 2 325 m), and gas exchange of *Rh. sachalinensis* was determined in the field condition (Yan *et al.* 1999a). In this experiment, the plants of *Rh. sachalinensis* that were strong and without pests were selected from the three plots and cultivated in the same environment condition at Harbin Experimental Forest Farm. After transplanting the above-ground part of the plants died and new leaves and shoots sprouted after a short time. The plants that grew well were selected and transplanted to the pots (3 plants each pot) and managed routinely for gas exchange measurement.

Measurement of gas exchange

Gas exchange of *Rh. sachalinensis* was measured with a LI-6400 Portable Photosynthesis System (LI-COR Inc., USA). The single leaf of the plant was too small to be measured, so whole twig was put into the

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leaf-chamber and the leaves faced to light for measurement. Leaf area was measured with a LI-3000A leaf area meter (LI-COR Inc., USA), and the data were input into LI-6400 Portable Photosynthesis System for recalculating net photosynthesis rate (Pn), transpiration rate (Tr) and other relative indexes. Respiration rate (Rd) equals to the negative value of measured Pn when the leaf-chamber was covered with a piece of black cloth. So Rd here is a respiration rate in day under dark, not a real respiration rate at night.

The date of curve of light dependent Pn was measured with LED light resource of LI-6400 Portable Photosynthesis System. Initial slope of curve of light dependent Pn was used as apparent quantum yield (AQY). The ratio of Pn to Tr was used as water use efficiency (WUE), which means CO_2 assimilation quantity with unit quantity water transpiration.

Gas exchange was measured continuously on sunny days from 7:00 to 18:00.

Results

Diurnal change of Pn of transplanted *Rh. sachalinensis*

Usually, diurnal change of photosynthesis rate in a plant (leaves) is similar to photon flux density (PFD) diurnal changes of photosynthetically active radiation (PAR). It's typical single-peak curve, and low in the morning and evening and high at midday. But when the plant is under stress such as soil drought or air drought diurnal change of photosynthesis rate will become typical double-peak curve (There is one peak in the morning and another peak in the afternoon with a midday depression, the peak in the afternoon is often lower than that of morning) or a special single-peak curve (Shen *et al.* 1998).

Diurnal change of Pn of transplanted *Rh. sachalinensis* was neither typical single-peak curve nor typical double-peak curve or special single-peak curve (Fig.1). At the same time the diurnal change of PAR, air temperature and air relative humidity showed no difference from those of the common condition (Fig. 2 to 4). The plants transplanted from the three habitats showed almost the same diurnal change of Pn, which is the highest at 7:00 and then decreased to the lowest at 15:00 to 16:00.

Though plants of Crassulaceae belong to CAM metabolism type, some species employ CAM only when the plants are under drought or salt stress (Larcher 1995a). The diurnal change of environment condition showed that during the time 7:00 to 11:00 the air temperature increased rapidly (Fig.3) and air relative humidity decreased sharply (Fig. 4) with the increase of PAR (Fig. 2). This sudden change might have stress effect on transplanted *Rh. sachalinensis*, so the CAM was employed and Pn decreased. The diurnal change of stomatal conductance (Gs) of transplanted *Rh. sachalinensis* (Fig. 5) can also prove this from another viewpoint. The Gs curves of transplanted *Rh. sachalinensis* is similar to that of Pn. Gs decreased rapidly after 7:00, this indicated the closing of the stomas. Stoma closing in daytime is one of the characters of CAM, but in this experiment stoma closing might be a kind of natural reaction of *Rh. sachalinensis* to the environment stress and not because of the employing of CAM.

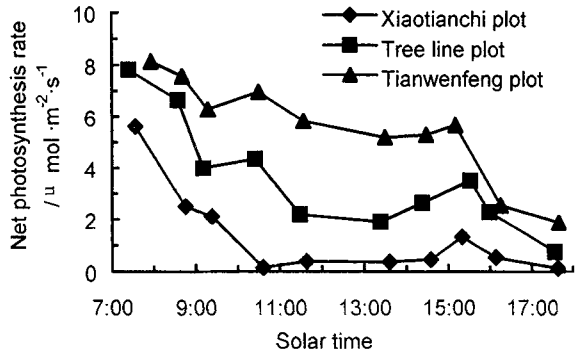

Fig. 1. Diurnal change of net photosynthesis rate (Pn) of *Rhodiola sachalinensis* transplanted from Changbai Mountain

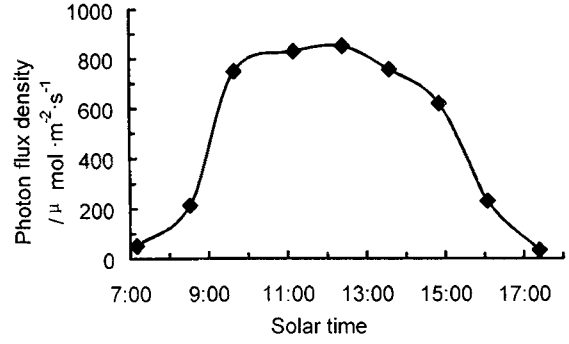

Fig. 2. Diurnal change of photosynthetic active radiation (PAR)

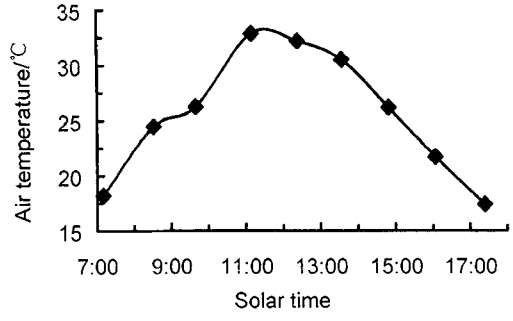

Fig. 3. Diurnal change of air temperature

Fig. 1 indicated that diurnal change of Pn of *Rh. sachalinensis* transplanted from different plots still had difference even they were cultivated in the same condition. Pn of *Rh. sachalinensis* transplanted from Xiaotianchi plot decreased rapidly after 7:00 and almost reached 0 at 10:30, then had a little increase at 15:30. So under the cultivation condition the photosynthesis time of *Rh. sachalinensis* from Xiaotianchi plot was very short (about 4 h) in a day. For the *Rh. sachalinensis* from Tree line plot, Pn decreased rapidly after 7:00, but the value was higher than that of Xiaotianchi plot. For the *Rh. sachalinensis* from Tianwenfeng plot, Pn remained at a high level until 15:30, and then began to decrease.

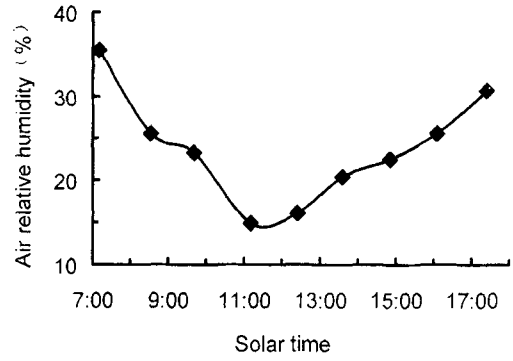

Fig. 4. Diurnal change of air relative humidity

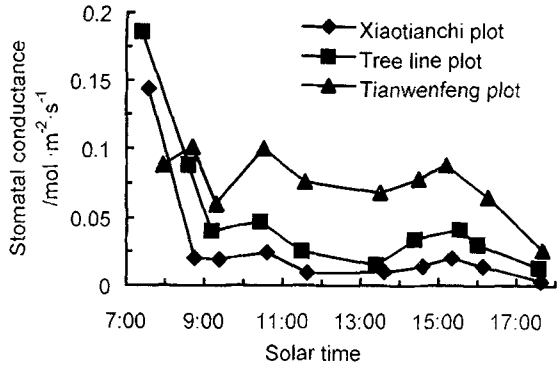

Fig. 5. Diurnal change of stomatal conductance (Gs) of *Rhodiola sachalinensis* transplanted from Changbai Mountain

AQY refers to assimilative quantity of CO_2 when plant receives unit quantity light. In practice, it often represents a rate of plant releasing oxygen under light or a rate of CO_2 assimilation, namely the ratio of Pn to PFD correspondingly. When being measured under low PED (generally photons for 50-150 μmol · m^{-2} · s^{-1}, means no surplus photon to be left), AQY will be manifested as maximum apparent quantum yield (Von Caemmerer and Farquhar 1981; Xu 1988; Shen 1992; Zhang *et al.* 1995). Here, the initial slope of curve of light dependent of Pn is taken as AQY, also as the maximum apparent quantum yield. AQY reflects to a certain extent CO_2 assimilation capacity of plant photosynthetic organ by making use of light energy under measurement condition, that is to say, reflecting photosynthetic capacity (Du *et al.* 1988; Yan *et al.* 1998).

Diurnal changes of AQY of *Rh. sachalinensis* transplanted from different habitats were generally similar. The value of AQY kept decreasing from 7:00 to 15:00, and slightly increased again after 15:00. The AQY value of diurnal change of *Rh. sachalinensis* transplanted from Tree line plot was almost higher than that of the plots of Xiaotianchi and Tianwenfeng (Fig. 6).

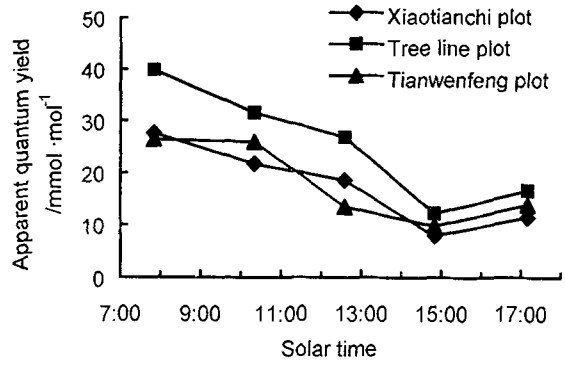

Fig. 6. Diurnal change of apparent quantum yield (AQY) of *Rhodiola sachalinensis* transplanted from Changbai Mountain

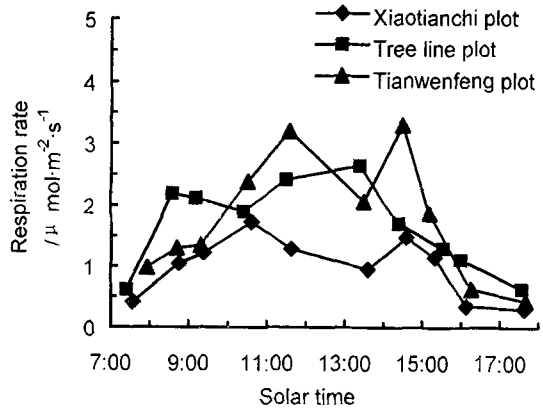

Fig. 7. Diurnal change of dark respiration rate (Rd) of *Rhodiola sachalinensis* transplanted from Changbai Mountain

The diurnal changes of Rd of *Rh. sachalinensis* transplanted from the three plots were measured under artificial shading. Diurnal changes of Rd of *Rh. sachalinensis* transplanted from different habitats

were all double-peak curves but the peaks of each curves showed at different position. The Rd peak values of *Rh. sachalinensis* transplanted from Xiaotianchi plot, Tree line plot, and Tianwenfeng plot showed at 10:36 and 14:35, at 8:35 and 13:23 and at 11:34 and 14:29, respectively (Fig. 7). As a whole, the peak value of Rd of *Rh. sachalinensis* transplanted from Tianwenfeng plot was higher than that of Xiaotianchi and Tree line plots.

Diurnal change of Tr of transplanted *Rh. sachalinensis*

As a physical process, Tr changes with steepness of the vapour pressure gradient between leaves surface and surrounding air. It also can be effected greatly by the radiation intensity, temperature and humidity (Larcher 1995c). The diurnal change of Tr of *Rh. sachalinensis* transplanted from Tianwenfeng plot was a single-peak curve and the peak showed at 11:34 (Fig. 8). This was corresponding with the diurnal changes of PAR (Fig. 2), temperature (Fig. 3) and relative air humidity (Fig. 4). The Tr of *Rh. sachalinensis* transplanted from Xiaotianchi plot and Tree line plot did not change much in the whole day and kept decreasing from the morning to the evening. But Tr of Tree line plot had some fluctuation (Fig. 8). The two curves were well corresponding to that of diurnal change of Gs (Fig. 5). This indicated that the diurnal change of Tr was greatly effected by stomas. Comparing Fig. 8 and Fig. 5, it can be seen that though the diurnal change of Tr of *Rh. sachalinensis* transplanted from Tianwenfeng plot responded well to PAR, air temperature and relative air humidity, it was still limited by stoma.

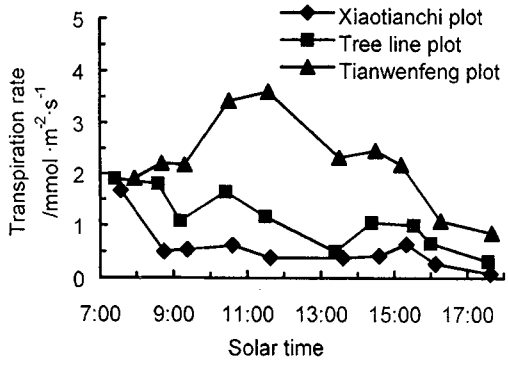

Fig. 8. Diurnal change of transpiration (Tr) of *Rhodiola sachalinensis* transplanted from Changbai Mountain

Diurnal change of WUE of transplanted *Rh. sachalinensis*

WUE usually can be divided into WUE of photosynthesis (WUE ph) and WUE of productivity (WUE p). WUE ph is the ratio of Pn to Tr and WUE p is the ratio of dry matter production to water consumption during the whole growing period (Larcher 1995b). Here WUE is WUE ph and only WUE ph may has diurnal change.

WUE of *Rh. sachalinensis* transplanted from Xiaotianchi plot changed violently in a day's time under cultivation condition. The highest value of WUE (at 8:45) was 20 times of the lowest (at 10:36). WUE of *Rh. sachalinensis* transplanted from the Tree line plot also changed very violently, but the extent of fluctuation was smaller than that of Xiaotianchi plot. WUE of Tianwenfeng plot didn't change much, it decreased from 7:56 to 11:34 and then kept stable with a little increase (Fig. 9).

Discussion

The Changbai Mountain locates at the eastern coast of the Asia continent and borders the Pacific. The vegetation showed obvious vertical belt of distribution because of the special temperate zone mountainous region climate. It's the only one treasury with the highest altitude in the northeast Asia continent for studying primeval Mountain vegetation (Zhang *et al.* 1981). *Rh. sachalinensis* is typical alpine plant that evolved morphological and physiological characters suitable for Mountainous environments in the long evolution. Diurnal change of Pn of transplanted *Rh. sachalinensis* has its own special character. This might be because of the peculiar physiological metabolism of *Rh. sachalinensis*. The diurnal change of gas exchange of *Rh. sachalinensis* is too difficult to be measured in the field because of the rainy and changeful weather. So we don't know the diurnal change of Pn of *Rh. sachalinensis* in the field condition and have no way to compare it with the diurnal change of Pn in cultivation condition.

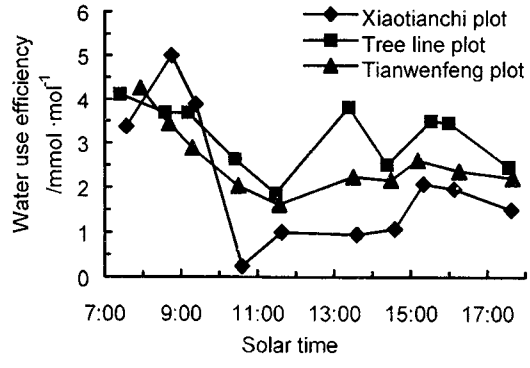

Fig. 9. Diurnal change of water use efficiency (WUE) of *Rhodiola sachalinensis* transplanted from Changbai Mountain

The three plots in the northern slope of Changbai Mountain are very different from each other. Gas exchanges of *Rh. sachalinensis* in the three plots are

also very different in the field condition (Yan *et al.* 1999a). After transplanted the newly sprouted part of above-ground showed the similar morphological character, but the gas exchange remained different from each other, just like in the field condition (Yan *et al.* 1999b). This experiment indicated that diurnal changes of gas exchange of transplanted *Rh. sachalinensis* from different plots were also different.

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